

High Frequency Coverage Prediction For EEMS.

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INTRODUCTION

The present day UK Royal Navy has an operational shortfall in the ability to determine the extent of its HF coverage from a single transmitter. It currently relies on HF prediction packages, primarily developed for Army antennae, that prescribe the optimum working frequency for a signal propagating between two points.

Work is being undertaken at the Maritime Warfare Centre (Gosport), supported by the UK Defence Research Agency Tactical Communications Department at Malvern, to develop a package that will enable the operator to assess the optimum working frequencies. The functionality will include an overlay routine outlining the extent of coverage within the geographical battlespace. Other benefits can be obtained from the package by assessing the risk of hostile interception in addition to supporting Electronic Support Methodologies.

This paper outlines the development work being undertaken to provide the Environmental Electromagnetic Modelling System (EEMS) HF module. The potential concepts of operational use are discussed along with future developments of the system.

THE REQUIREMENT

The primary aim for a HF propagation prediction system is for timely and accurate predictions to support tactical exploitation of RN communications equipment. It should also be hosted on a system for eventual incorporation into the RN EEMS Project [Moore and Lewis, 1994].

BACKGROUND AND EXISTING HF PLANNING AIDS

“There is currently no HF prediction tool covering both Skywave and Groundwave available to the tactical commander to assist with either

HF/DF or countersurveillance ”[Moore and Lynch 1996]. However, there are software packages, paper documents and equipment available to the RN to assist in the planning of HF frequencies, such as the GEC Marconi Orange Book, MICROPS II, NAVMUF Program and the oblique CHIRPSOUNDER Equipment.

To assist the user in initializing the different software programs, a daily Short Term Ionospheric Forecast (STIF) is produced as an input to the program to determine the nature of the ionosphere (e.g. SSN, 10.7 flux). The following is a description of the models available.

MICROPS II

MICROPS II, based on the CCIR recommendation model REC533, only considers the Skywave element. The software operator and paper documents require detailed knowledge of the antennae and the power levels that are to be used for the transmissions. The outputs given by the program are a series of charts that detail the Maximum Useable Frequency (MUF), Lowest Useable Frequency (LUF) and the Frequency of Optimum Transmission (FOT) for a particular transmission. Within these charts, the program highlights which of the specified frequencies are likely to support the propagation over a given path. The groundwave component of the signal is not calculated. Following the release of the GEC-MARCONI Orange Book software, MICROPS II is no longer used.

GEC Marconi Orange Book

Originally issued to the FLEET in a hardcopy format, this package is now issued on an annual basis on a 3.5” floppy diskette. The orange book software, based on the CCIR REC894 Skywave prediction package, calculates the predictions for both Skywave and Groundwave propagation and is originally designed for applications using Army

antennae. The program is executed in the DOS environment of a PC.

The use of navy antennae has not been fully implemented. Assumptions, therefore, have to be made for RN transmitter and receiver antenna parameters. The results are based on two outputs; Signal-to-Noise Ratio Graphs and Frequency Tables.

*Signal-to-Noise Ratio Graphs*

- These graphs show the frequencies which will support propagation on the circuit at each time of the day. Each graph depends on the particular sunspot activity, season and equipment parameters that are chosen from the list of input parameters. In general, the highest frequency envelope is governed by the state of the ionosphere whereas the lowest frequency envelope is more sensitive to the type of equipment that is used eg. radiated power, antenna choice, modulation type, etc.

*Frequency Tables*

This table shows the lowest, recommended and highest frequencies that will achieve the required grade of service for the particular equipment and modulation type chosen for each 2 hourly segment of the day. These minimum and maximum frequencies correspond to LUF and MUF envelopes shown in the signal-to-noise ratio graphs.

It is not possible to configure the software according to the communications plan inputs and equipment onboard the surface vessel. As a consequence, the results may be of little use to the operator.

**There is a groundwave option built into the software for the Orange Book program. It is not possible to display the results for the groundwave simultaneously with the skywave results.**

*NA VMUF Program*

The Naval Maximum Useable Frequency (NAVNUF) program enables the HF path length, the MUF and FOT between two stations to be calculated. There are the usual parameter inputs comprising the Latitude and Longitude positions of the transmitter and receiver sites and the date

and time of day for the transmission as is common with all HF prediction programs. The results are a hard copy printout detailing the MUF and the FOT at hourly intervals for the required period and are based on the Skywave component. No indication as to the extent of the Groundwave is given.

*CHIRPSOUNDER*

A Chirpsounder system can simultaneously provide path sounding and frequency occupancy monitoring as an aid to 'real-time' HF frequency management. The Chirpsounder measures the propagation conditions in the HF band between a low power transmitter and a receiving station. Displays at a receiving station enable the operator to select the most suitable channel. Additional equipment details the current channel occupancy and those available for use.

The shore transmitters radiate continuously and may be used by ships to predict the best frequency range for use on HF Ship/Shore, Broadcast and Maritime Rear Link (MRL) services. The system provides the user with frequency information that will reach the receiver site (e.g. the Barry RCS5 gives the integrated power for all transmission delays). This is not always the most tactically useful frequency as no consideration is given to where the transmission propagates.

**idealised HF Decision Aid**

An assessment of the current HF prediction tools available has been carried out with a view to selecting the most appropriate software that achieves the majority of the requirements outlined earlier. A HF decision aid system [Shukla and Cannon, 1994] should ideally comprise of three elements; an information gathering and distribution system; a jamming and interception model and a communications system interface.

The displays afforded by the decision aid are the key to the success of such a system. For operational use, the user does not wish to be presented with endless pages of text. It is considered that the most tactically useful display is that of a map detailing the area of interest with the coverage of the transmission superimposed.

HF Decision Aid

A HF decision aid (The Jamming and Intercept Vulnerability Estimator (JIVE)) was originally devised by the Defence Research Agency at Malvern under the 19g programme in support of RAF requirements. This decision aid calculates both the skywave and the groundwave coverage [Shukla and Cannon, 1994].

In general, the function of the decision aid may best be defined as *“an automated decision aid to predict, using near real-time environmental and systems information, those communications parameters (e.g. frequency, power, receiver station location) which minimise communications vulnerability”*. [Shukla and Cannon, 1995]

The difference between the DRA decision aid and other HF propagation models is that the decision aid incorporates a Jamming and Interception Model (JIM). The JIM allows the user to input information relating to hostile and friendly forces (e.g. hostile locations from intelligence gathering units), Electronic Support Measures (ESM) and Electronic Protective Measures (EPM) in addition to environmental data. The ionospheric model currently used comes from the conventional HF systems prediction program REC533A. [CCIR, 1994] The Groundwave component of the JIVE system is based on the commercial GR-WAVE prediction package [CCIR, 1994]. The system is described in more detail by Shukla et al [1996].

REC533A employs a median model ionosphere during its calculations and, as such, has been acknowledged by the CCIR and ITU as being of sufficient accuracy to be used for propagation prediction software. This acknowledgement, together with the knowledge that the precursor to REC533A, REC894 (also using a median model ionosphere), has been used operationally by the RN (MICROPS II), will alleviate the need for the RN to conduct evaluation trials on the propagation software.

HF EEMS

HF EEMS has been designed using the empirical version of the JIVE system. This was originally developed in the DOS environment, relying on the memory allocation utilities within this setup. As a

consequence, the JIVE system was not fully compatible with MS WINDOWS. With the primary aim of the HF EEMS system being for incorporation into a WINDOWS-based package, it became apparent that major user-interface alterations had to be made to the JIVE software.

The HF module of the EEMS software is designed to operate using a two-tier operating procedure; the operator mode and the expert mode. All the functionality that is present in the operator mode will be present in the expert mode with the additional editors that are required to update the databases held within the system.

Input Parameters

The ergonomics of an operational package to be used at sea by the RN is paramount to the success of the software. With this in mind, the HF EEMS development has concentrated on the Graphical User Interface (GUI) to minimise the operations required and reduce the specialist information required to operate the system successfully.

The main control screen that the user encounters is a scenario editor based on the antennae at the transmitter, the friendly receivers and the hostile receivers. The power output is initialised and the communications plan that the ship is operating to is initialised. This initialisation screen is shown at figure 1.

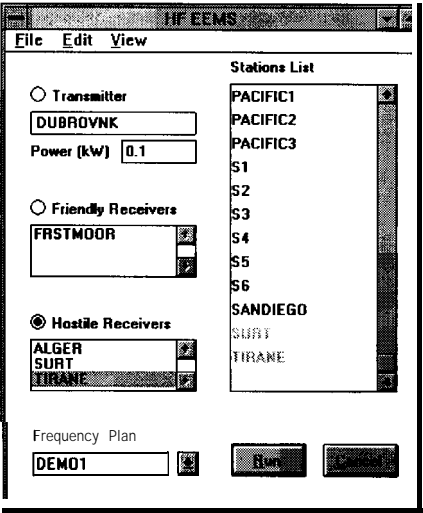


Figure 1: HF EEMS Parameter Input

On initialisation of the package, the sunspot number for predictions is read from a file, with

SSN predictions obtained from NCCOSC or other world data centres. The current time of the PC is also used to produce HF coverage predictions for the current time of day. The user is able to alter these inputs in order to produce coverage prediction for any time of year, thereby enabling the package to be used for future planning of exercises.

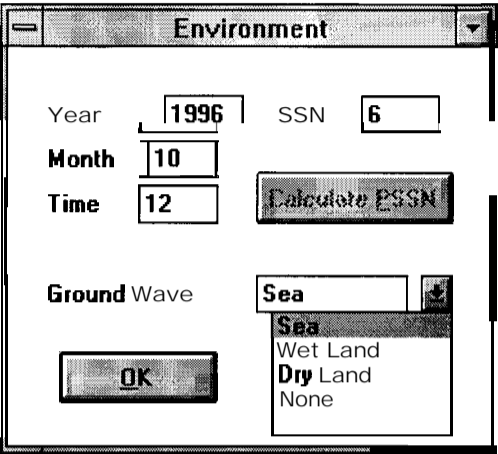


Figure 2: Prediction Time/Groundwave Editor

The groundwave editor is located in the environment editor screen. This allows the user to select the most appropriate ground type that is at the transmitter location. Currently, the package defaults to the Sea option owing to the main user being the at-sea communicator. It must be stressed that the results produced from the groundwave calculations are a crude representation. The package does not take into account the differences in the ground type as the signal propagates from its transmit site to the receive site. As a result of the EEMS system having a resident geographical information system (GIS), future improvements to the package will enable HF EEMS to access the groundtype cover for assessment of any groundwave attenuation.

The user is able to select the transmitter and receiver sites from a database within the program. If any of the transceivers are mobile the location of the antenna can be inserted manually, either from its Latitude and Longitude co-ordinates or from a location on a map of the area. The eventual host for EEMS will be the RN's Command Support System (CSS), which will enable the locations of all mobile sites to be inserted automatically from the GPS systems and General Operations Plot (GOP) located in the Ship's operations room. Any new receive

sites can be inserted into the package from the site editor as described. The edit function for the transmitter and receiver sites can be accessed from the operator mode by clicking on the station in the selection box. This same method can be used in the expert mode, with an additional editor for updating the database of stations.

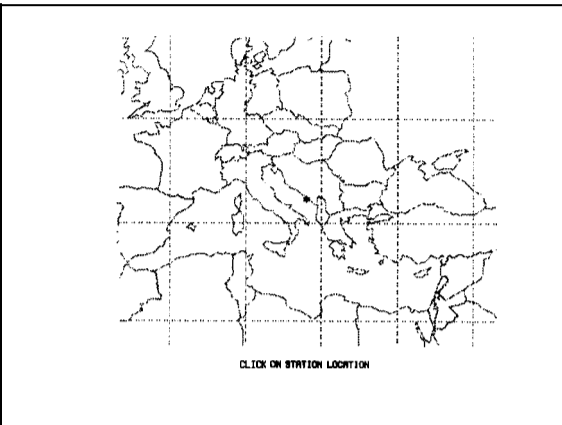


Figure 3: Station Editor Input Screen

The other parameter inputs that are required from the package are the development of the frequency communications plans. These will be created before a ship deploys on an exercise or an operation. The capabilities are only available in the expert mode of the software. The communications plan comprises a list of frequencies that are available to the ship at any given period of time. These are normally promulgated to the ships before an exercise or an operation takes place. An example of the communications plan editor is given at figure 4:

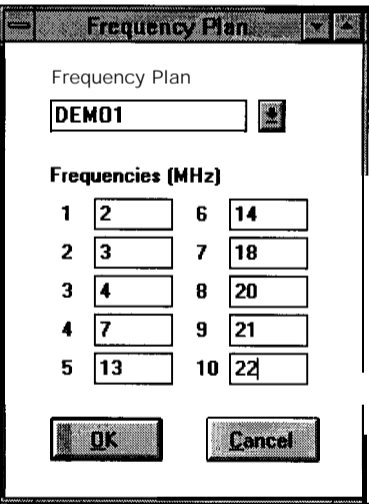


Figure 4: Communications Plan Editor

Also available in the expert mode is the ability to create new transceiver sites. The current version of the propagation tool bases all its predictions on an isotropic commercial aerial. This is a simple representation of the RN transmitters, however further development is anticipated to include aerials specific to ship and shore bases. The information that is required from the station editor is shown at figure 5

Station Details

Station ID

DEMONSTRATION

Change Location

Height [m]

0

Bandwidth [Hz]

3000

Min Elevation (deg)

3

Ambient Noise [dBW]

-140

Bearing (deg)

0

Required SNR [dB]

0

Required Time [s]

50

OK

Cancel

Figure 5: Station Editor

Database Population

Prior to deployment on an exercise or operation, it is necessary to populate the station and communications plan databases. This will be carried out in the operator mode. However, the aim of the EEMS system is to work in conjunction with the Royal Navy’s FLEET Data Management Unit (FDMU) which provides all relevant data for each of the ships’ systems. It is anticipated that the FDMU will hold station information for populating the HF EEMS module.

Display Modules

The powerful functionality of the HF module for EEMS is concentrated in its display utilities. The majority of current day HF propagation prediction systems are either based on the skywave component or the groundwave component of the signal. HF EEMS allows for both components of the wave to be displayed simultaneously.

Coverage map displays can also be varied according to the requirements of the user. This can range from the simple dB pathloss of the signal to the signal to noise strength ratio for any part of the Area of Interest (AOI).

This aspect of coverage mapping is of great advantage to the tactical communicator. The coverage displays that are calculated detail a single frequency from a selection of those frequencies of interest to the user; eg the communications plan. The coverage displays allow the user to analyse multiple skips occurring with the skywave element of the transmission.

The output screens are controlled from a single controller. This control unit remains the same for both the expert and the operator modes with additional functionality available to the expert user. Essentially, there are two parts to the control panel for the display section; the coverage plots and the frequency plots.

HF-EEMS Display

Coverage Plot

Type

Sky-wave Map

Signal

SNR

Frequency

3.0

Freq Plan

DEMO1

Frequency Plot

Type

Frequency Table

Frequency Plot

Cancel

Figure 6: HF-EEMS Display Controller

It is the former of the two types that demonstrates the improved capability of the idealised HF propagation system. There are two types of displays that can be obtained from this section. These detail the Signal Power level, in relation to the distance that the signal has propagated, and the Signal-to-noise ratio signal coverage.

The Signal Power display diagram has been modified for the operator; the power level of the signal is represented by a scale of 1 to 10, with 10 being the strongest signal strength. It is intended that the expert user will have the option to display -- the power displays as a function of dBs.

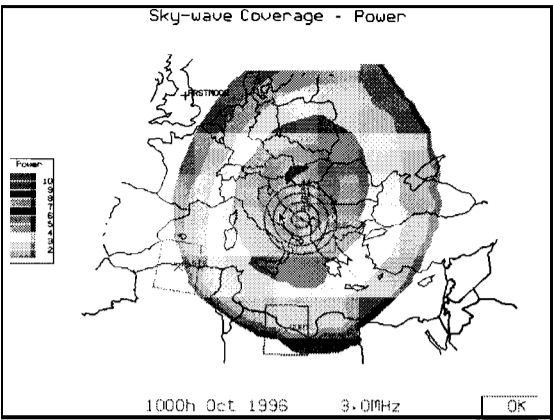


Figure 7: HF EEMS Power Level Display

The second graphical output for the mapping system details the signal to noise ratio of the signal at a particular site. This, tactically, is more useful than the former display. The ambient background noise levels are taken into account, thereby requiring a greater sensitivity in the receive equipment to potentially intercept a stray signal.

It can be noted that the coverage differences are apparent between figures 7 and 8. The additional benefit of the SNR plot highlights the significant effects of the background noise levels around the area of interest.

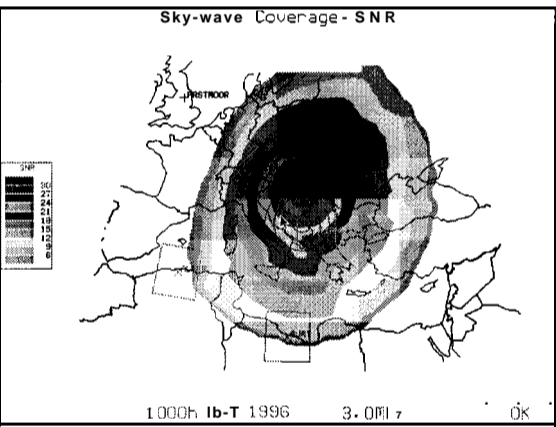


Figure 8: SNR Display Screen

The groundwave component of the signal is shown in both the Power and SNR displays as concentric circles based around the transmitter site.

There are a variety of outputs that can be obtained from the JIVE system. These range from the typical FOT/MUF diurnal plots that are given in the standard HF prediction programs to the displays of

maps with the transmission coverage overlaid. This coverage can be a combination of both the skywave and the groundwave elements of a HF transmission, or the user can display a single component.

The groundwave component of the transmission can also be calculated and the coverage plotted onto the map of the AOI. This facility will enable the user to determine those frequencies that are more conducive for tactical communications within a task group.

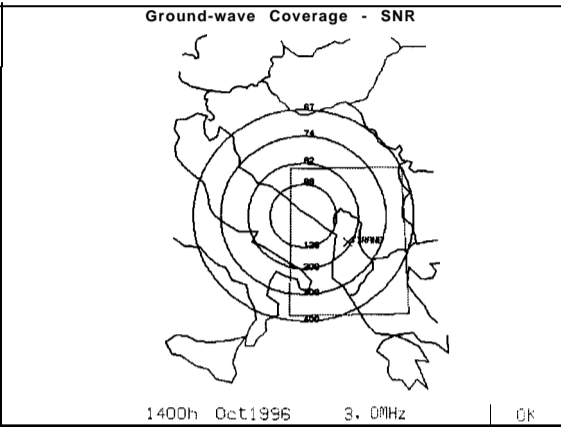


Figure 9: Groundwave Coverage Plot

The second component of the Display Controller concentrates on the traditional HF prediction plots. There is, however, additional **functionality** to this section in the guise of information relating to the hostile intercept sites (HIS). The traditional MUF and LUF plots are detailed in the chart shown at figure 10. There are additional curves detailing the MUF for the hostile receivers. At the top of the graph denotes which of the friendly receivers is the most secure station between the UT hours. If there were more than one friendly station, this graph would denote the composite operational MUF.

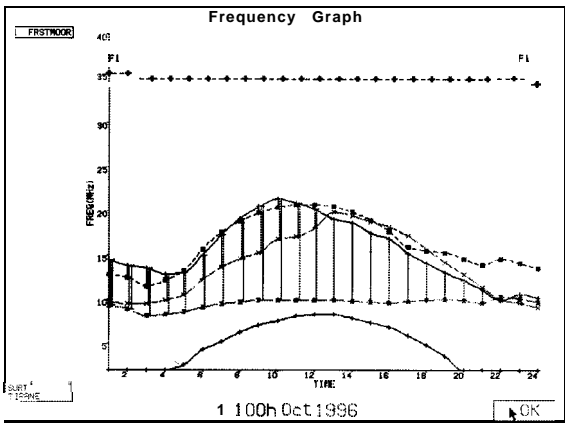


Figure 10: A 24 hour MUF prediction graph

Other displays that can be obtained from the display controller denotes a 24 hour minimum interception frequency schedule. This is a colour coded schedule which recommends frequency ranges and the optimum friendly receiver stations that should be used to minimise interception. The hostiles are listed with the highest friend-to-hostile operational MUF first. Hostiles predicted to receive the signal are indicated by an asterisk. If all hostiles intercept the signal, then no frequency range is approved and a blank line is displayed. It should be noted that signal interception by at least three hostiles is required for accurate position fixing

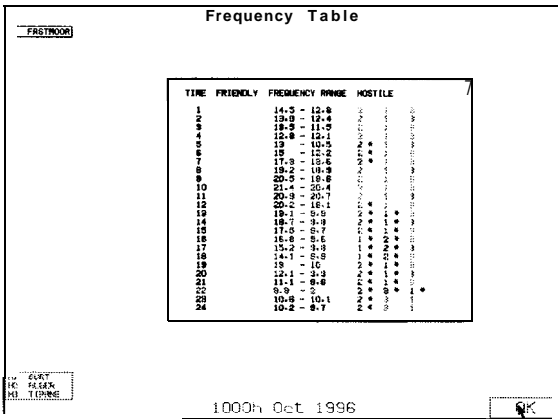


Figure 11: A 24 hour minimum interception frequency schedule

### FUTURE DEVELOPMENTS

Although the future development of the HF EEMS module has been described by Shukla et al [1996],

the main points affecting the future use of EEMS are outlined as follows:

There are plans to incorporate a pseudo sun spot number, calculated from updated results using the onboard Chirpsounder equipment. This will provide an improvement in the MUF that are calculated. Plans are also underway to make more use of the LUF in the decision making routines of the package. Other plans include an improved antenna model developer. This will allow the package to be ported across to other users in the military field, where different antennae are used for HF communications.

### CONCLUSIONS

The current HF propagation packages that are available to FLEET do not meet the specified requirements. None of the packages assists the user in selecting the LRI/LPI frequencies from the communications plan. Chirpsounder equipment enables the user to establish a propagation path for effective transmission. It does not calculate LRI/LPI frequencies.

The benefits to the RN in using the HF EEMS system encompass more than simple HF frequency management. With the ability to plot hostile and friendly locations, the coverage obtained from a transmission can be controlled. The facility to input receiver sensitivities into the model may provide the Electronic Warfare (EW) and Intelligence Community with possible counter detection and CESM benefits.

It can be seen that different interpretations of results obtained from HF prediction programs can alter the use of the tools altogether. Before the implementation of the HF EEMS package, the RN were in no position to determine the extent of coverage that their HF signals were achieving. It is now possible to have greater control on the management of HF circuits and a revised methodology for achieving a secure HF propagation path.

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